IMPLANTABLE CURRENT COLLECTOR ID MATRIX IDENTIFIER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. provisional patent application Serial No. 60/413,076, filed on September 24, 2002.

BACKGROUND OF THE INVENTION

The present invention relates to the conversion of chemical energy to electrical energy. More particularly, the present invention is directed to the precise regulation of the gram amount of electrode active materials contacted to the opposite sides of a current collector. The precise weight of the current collector is also regulated within strict tolerance. Current collectors that are outside the weight criteria, whether before being contacted with the electrode active material or after, are rejected as being out of tolerance. The strict regulation of the weight of the electrode active material in a cell is particularly important when different active materials are contacted to opposite sides of the current collector. Such a configuration has, for example: silver vanadium oxide (SVO)/current collector/fluorinated carbon (CF_x), and it is important that the weight ratio of active materials is closely regulated for proper cell functioning.

SUMMARY OF THE INVENTION

The present invention relates to a cell including a cathode having a second cathode active material of a relatively high energy density but a relatively low rate capability sandwiched between two current collectors and with a first cathode active material having a relatively low energy density but a relatively high rate capability in contact with the opposite sides of the current collectors. It is important for proper cell functioning that the weight ratio of the first and second cathode active materials is within a strict tolerance. Further, it is important to be able to track and record this information, as well as other data, for each cell built in a production facility. Marking the current collectors with an identifying I.D. matrix that is read and recorded for each electrode and each cell does this.

The present cell is useful for powering an implantable medical device, such as an automatic implantable cardioverter defibrillator, cardiac pacemaker, neurostimulator, drug pump, bone growth stimulator, and hearing assist device.

These and other objects of the present invention will become increasingly more apparent to those skilled in the art by reference to the following description and to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view, partly broken away, of an electrochemical (word missing) 10 accordingly to the present invention.

Fig. 2 is a plan view of a current collector 30 including an ID matrix identifier 62.

Fig. 3 is an enlarged view of the indicated area on Fig. 2.

Fig. 4 is an exploded view of one embodiment of a sandwich cathode 32 of the present invention.

Fig. 5 is a flow chart depicting the steps for building a cathode electrode according to the present invention.

Fig. 6 is a flow chart depicting the steps for building an electrochemical cell including the cathode assembled according to Fig. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a perspective view of an exemplary electrochemical cell 10. The cell 10 includes a casing 12 housing an electrode assembly of an anode electrode comprising a plurality of anode plates 14 and a cathode electrode comprising a plurality of cathode plates 16 prevented from directly contacting each other by an intermediate separator 18. The anode/cathode electrode assembly is in a prismatic configuration housed in the deep-drawn casing 12 closed by a lid 20.

The lid 20 includes an opening supporting a terminal lead 22 insulated from the lid by an insulating glass 24. This structure is commonly referred to as a glass-to-metal seal. The terminal lead 22 is connected to one of the electrodes, typically the current collector (not shown in Fig. 1) for the cathode electrode, and serves as the positive terminal. The current collector for the anode electrode is connected to the casing 12 or lid 20, or both, which serve as the negative terminal. This type of cell construction is referred to as a case-negative configuration. A case-positive configuration has the cathode connected to the case and the negative electrode connected to the terminal lead 22. An activating electrolyte is filled into the other lid opening 26 and a closure member 28 hermetically sealed therein completes the cell 10.

While the exemplary cell 10 shown in Fig. 1 is of a prismatic design, the present invention is not intended to be so limited. In a broader sense, the present system is useful with many different types of cell designs including those of jellyroll or spirally-wound electrode assemblies, button-type cells, coin-cells, and the like. The present system is also useful with capacitors of either an electrochemical, electrolyte or hybrid design. This is what is meant by the term "electrical energy storage device" as used in this description.

Fig. 2 shows a current collector 30 of a structure useful with the electrode 32 shown in Fig. 4. The illustrated electrode 32 is a cathode, although the present

invention is equally applicable to an anode electrode. The cathode comprises a first current collector 30A and a second current collector 30B. The current collectors 30A and 30B are essentially identical and their structure will be described in detail with respect to the illustrated current collector 30 of Figs. 2 and 3.

The current collector 30 comprises opposed wing sections 32 and 34 connected together by an intermediate tab portion 36. The tab 36 supports spaced apart projections 38 and 40. The latter projection 40 has an aperture 42 while an aperture 44 is spaced a short distance inboard from the former one (Fig. 3). The projections 38, 40 and apertures 42, 44 serve as indexing structures for accurately and repeatably positioning the current collector in a fixture for building the electrode, as will be explained in detail hereinafter. The current collector wing sections 32, 34 each comprise an open grid structure 46, 48, respectively, providing them in the form of a screen, and the like. One preferred method for providing the open grid current collectors is described in U.S. Patent No. 6,110,622 and 6,461,771, both to Frysz et al. These patents are assigned to the assignee of the present invention and incorporated herein by reference.

As shown in Fig. 4, an electrode, for example a cathode electrode, is built by positioning in an appropriately shaped fixture (not shown) a pair of blanks 50 and 52 of a first electrode active material, for example SVO, followed by the first current collector 30A having its respective wings positioned on top of the blanks. Blanks

54 and 56 of a second electrode active material, for example CF_x, are positioned on top of the opposite sides of the wings of current collector 30A.

The second current collector 30B is then positioned on top of the second electrode active material blanks 54, 56 opposite the first current collector 30A. Finally, two blanks 58 and 60 of a third electrode active material, for example SVO, are positioned on the wings of the current collector 30B opposite the second electrode active material.

This assembly is then subjected to sufficient pressure to intimately contact the active materials to the opposite sides of the respective current collectors 30A, 30B. Direct bonding contact with the current collector sides is important to prevent delamination. However, it is also important that the SVO and CF_x materials are segregated to their respective current collector sides so that the active material/current collector interfaces are not "contaminated" by the opposite active material. In other words, it is important that one active material does not migrate through the screen grid to the other side of the current collector to interfere with direct bonding of the other active material to the current collector surface.

The thusly assembly electrode assembly is referred to as a "sandwich electrode". A preferred form is a cathode electrode with the first and third active materials of a greater rate capability, but a lesser energy density than the intermediate second active material. The second active material has a greater energy density, but a lesser rate

capability than the first and third active materials. Silver vanadium oxide is preferred for the first and third active materials while CF_x is preferred for the intermediate second active material.

In a broader sense, it is contemplated by the scope of the present invention that the first and third active materials of the present sandwich cathode design are any materials that have a relatively lower energy density but a relatively higher rate capability than the second active material. In addition to silver vanadium oxide, copper silver vanadium oxide, V_2O_5, MnO_2, $LiCoO_2$, $LiNiO_2$, $LiMn_2O_4$, TiS_2, Cu_2S, FeS, FeS_2, copper oxide, copper vanadium oxide, and mixtures thereof are useful as the first and third active materials, and in addition to fluorinated carbon, Ag_2O, Ag_2O_2, CuF_2, Ag_2CrO_4, MnO_2 are useful as the second active material. Even SVO is useful as the second active material when copper silver vanadium oxide is the first and third active material. For a more detail description of a "sandwich" electrode design, reference is made to U.S Patent No. 6,551,747 to Gan, which is assigned to the assignee of the present invention and incorporated herein by reference.

In order to regulate the manufacturing process for the sandwich electrode, each of the current collectors 30A, 30B is provided with a unique identification code or ID matrix 62. The ID matrix 62 is preferably etched, such as by a laser, onto the connecting tab 36. This provides the matrix with a smaller footprint than a typical bar code, thus minimizing warping of the current collector due to

excessive heat. Etching is also preferred because it is permanent and will not contaminate the cell as an ink jet marking system might.

Figs. 5 and 6 are flow charts illustrating an industrial production line for precisely and accurately controlling the processes that constitute the manufacture of the sandwich electrode and, more generally, the associated electrochemical cell 10. The processes begin with a bulk CF_x powder input 64, a bulk SVO sheet coupon input 66 and a current collector input 68. First moving along the CF_x flow path, the bulk powder is moved to a sifter 70 that separates out or sieves out any particles greater than a specified size. The sifted out particles are moved to a pulverizer (not shown) that comminutes them to the desired size before they are re-introduced into the sifter. The CF_x powder leaving the sifter is filled into a fixture having the precise shape of the product cathode electrode. A specified weight amount of CF_x powder in the fixture is leveled smooth 72 and then pressed with sufficient force to form a blank 74. The blank 74 is weighed on a tare scale 76, and if it is within tolerance, moved to a holding bin. If not, the blank is rejected as being out of specification 78. In order to pass tolerance, a CF_x blank must be within at least about ±0.1 grams of a specified weight and, more preferably, within about ±0.005 grams of a specified weight.

Formation of an SVO blank takes place in a somewhat different manner. Silver vanadium oxide blank formation is carried out according to the process described in U.S.

Patent Nos. 5,435,874 and 5,571,604, both to Takeuchi et al. These patents are assigned to the assignee of the present invention and incorporated herein by reference. As described in the Takeuchi et al. patents, a freestanding active sheet or coupon is made from SVO of a specified granular size, carbon black or graphite as a conductive additive and a powder fluoro-resin binder such as PTFE powder. These ingredients are mixed in a solvent of either water or an inert organic medium such as mineral spirits. The resulting paste is either run through a series of compacting roll mills to form a thin sheet having a tape form, or it is turned into briquettes that are then calendered into the freestanding sheet as a continuous tape. In any event, the tape is subjected to a drying step that removes any residual solvent or water and then moved to a machine that punches coupons 66 from the tape. The coupons 66 are transferred to a blanking station where a hydraulic press having platens or fixtures presses them into blanks 80 of the precise shape of the product cathode electrode. Each blank 80 is weighed on a tare scale 82, and if it is within tolerance, moved to a holding bin. If not, the blank is rejected as being out of specification 84. In order to pass tolerance, a SVO blank must be within at least about ±0.1 grams of a specified weight and, more preferably, within about ±0.005 grams of a specified weight.

The current collector input 68 begins with a bin holding a plurality of the current collectors 30 (Fig. 2). A chemical machining process, such as described in U.S.

Patent Nos. 6,110,622 and 6,461,771, both to Frysz et al., preferably produces the current collectors. These patents are assigned to the assignee of the present invention and incorporated herein by reference. The current collectors 30 are moved to an etching station 86 where the ID matrix 62 is applied to the connecting tab 36. The etched current collector is moved to a reader 88 that electronically confirms the ID matrix marking 62. After ID matrix confirmation, the current collector is weighed on a tare scale 90, and if it is within tolerance, moved to a holding bin for the etched and weighed current collector screens 92. If not, the current collector is rejected as being out of specification 94. In order to pass tolerance, a current collector must be within at least about ±0.1 grams of a specified weight and, more preferably, within about ±0.006 grams of a specified weight.

The thusly-manufactured CF_x blank 74, SVO blank 80, and current collectors 92 are then fed to a linear slide equipped with a Cartesian robot 96. This machine is programmable to assemble the three input components into any one of a number of different electrode configurations.

One is of a sandwich cathode as shown in Fig. 4 having the dual wing current collectors 30A, 30B each of a configuration: SVO/current collector/CF_x/current collector/SVO. Another preferred embodiment is of the same configuration but without the current collectors being of a dual wing construction. Another preferred embodiment is of the configuration: SVO/current collector/SVO/CF_xSVO/current collector/SVO. Still another preferred embodiment is of

the configuration: SVO/current collector/CF_x with the SVO side facing the lithium anode. This latter cathode configuration provides a cell referred to as a "medium-rate design". The others are referred to as being of "high-rate designs".

Regardless of the specific type of cell being built, the finished cathode leaving the Cartesian robot 96 moves to a tare scale 98 where a final weight is recorded. This weight must be within $\pm 5\%$ of the cumulative weights of the respective CF_x blanks, SVO blanks and current collectors, or the cathode is rejected 100 as being out of specification. After final weighing, the cathode electrode weight is checked and the ID matrix 62 etched onto the current collectors are scanned 102. The ID matrix associated with the readings of the final weights of the various component blanks and current collectors 104 is recorded 106 in the memory of a central processor unit, or it is recorded in some other tangible medium such as on a disk, print out, and the like.

Fig. 6 is a schematic representation of a cell constructed having one or more of the cathode configurations described with respect to Fig. 5. While not shown in the drawing, the cell has an anode as a continuous elongated element or structure of an alkali metal, preferably lithium or a lithium alloy, enclosed within a separator and folded into a serpentine shape. A plurality of cathode electrode assemblies with an associated ID matrix 108 produced according to the component flow chart of Fig. 5 are then interposed between the anode folds. In

the case of the cathode shown in Fig. 4, the spaced apart plates are folded relative to the connecting tab 36 so that there is a portion of the anode disposed along opposite major sides or each cathode plate. The cell illustrated in Fig. 6 has two dual wing cathode electrode structures and a fifth cathode plate not of a dual wing construction.

The cathode plates interleaved between the folds of the serpentine anode are fitted inside a suitably sized casing 12 that itself has been provided with a laser etched ID matrix. The case ID matrix is scanned 110 and this data is also recorded for later retrieval. That way, there is a permanent record of each cell detailing the specific electrode configurations with the exact weights of the various active blanks and current collectors housed in a specific casing. The cell is activated with an electrolyte such as of $LiPF_6$ of $LiAsF_6$ dissolved in a 50:50, by volume, mixture of propylene carbonate and 1,2-dimethoxyethane. For a case-negative cell design, the current collector of the serpentine anode is connected to the case or lid, or both, and the current collector connecting portions 36 are connected to the terminal lead 22. If a case-positive design is desired, the reverse is true.

One exemplary form of the ID matrix 62 includes a cell model number and a unique serial number. An example is the twenty-character sequence 20770000000000000001. The first four numbers designate the cell as a model 2077 cell, and the following 16 characters are the cell's unique serial number.

In a sandwich electrode design, it is important that the weight ratios of the high rate active material, for example SVO, to that of the high-energy active material, for example CF_x, be within a strict tolerance. In a lithium electrochemical cell, a sandwich cathode having the configuration of: SVO/current collector/ CF_x /current collector/SVO, provides for the high volumetric capacity CF_x active material being quantitatively converted into or used as the high power energy of the SVO material. In that respect, it is believed that during high energy pulsing, the SVO material provides all the discharge energy. Above the discharge voltage of the CF_x electrode material, only SVO electrode material is discharged, providing all of the energy for pulsing as well as for any background load discharging. Under these discharge conditions, the CF_x active material is polarized with respect to the SVO material discharge voltages. Then, when the lithium cell is discharged to the working voltage of the CF_x material, both the SVO and CF_x materials provide the energy for background load discharging. However, only the SVO material provides energy for high rate pulse discharging. After the SVO active material is pulse discharged, the potential of the SVO material tends to drop due to the loss of capacity. When the SVO background voltage drops below the working voltage of the CF_x material, the SVO material is charged by the CF_x material to bring the discharge voltage of the sandwich cathode materials to an equal value. Therefore, it is believed that the SVO material acts as a rechargeable electrode while at the same time the CF_x

material acts as a charger or energy reservoir. As a result, both active materials reach end of service life at the same time.

Thus, it is important for the proper functioning of a lithium cell containing a sandwich cathode of, for example the configuration of: SVO/current collector/CF_x/current collector/SVO, to have the weights of the respective active materials properly regulated within strict tolerances. This is accomplished by the use of the ID matrix etched onto the current collectors and the casing of the present cells. As previously discussed, other sandwich cathode configurations include: SVO/current collector/SVO/CF_x/SVO/current collector/SVO and SVO/current collector/CF_x with the SVO facing the lithium anode. In these alternate embodiments it is also important to strictly regulate the weight ratios of the active materials. The ID matrix can also be etched onto the anode current collector for tracking that component as well.

It is appreciated that various modifications to the inventive concepts described herein may be apparent to those of ordinary skill in the art without departing from the spirit and scope of the present invention as defined by the appended claims.